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(54) AUTOMATIC ON-OFF ELECTRONIC SWITCH

(71) We, AMERICAN MEDICAL ELECTRONICS CORPORATION, a Corporation organised and existing under the Laws of the State of Massachusetts, United States of America, of 26 Rockway Avenue, Weymouth, State of Massachusetts, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to an electronic thermometer having an automatic electronic switch for independently holding the system on for a limited time and then automatically turning it off to conserve power.

Recent advances in technology have made more appealing the widespread use of electronic thermometers to measure temperature, especially in the medical field. Such thermometers usually include a thermometer unit and a temperature sensing probe unit which may be used with disposable covers. These systems are initially relatively expensive compared to mercury thermometers but over their useful life they are less expensive and time-consuming to use. However, since these thermometers are electronic they require electrical power for their operation which is supplied in the form of batteries to promote the portability of the electronic thermometer systems. The system requires substantial electrical power to operate the sensing and measuring circuits and to operate the display; as a result the batteries may be relatively quite large and heavy in order to provide sufficient power for operating the system over a reasonable period of time. Periodically the batteries are removed and replaced with new ones at additional cost or the system is removed from service while the batteries are recharged. Poorer battery duty cycles result if the user habitually unnecessarily extends the measuring and display period or inadvertently fails to switch off the system at the end of its use.

The invention provides an electronic thermometer system comprising a temperature sensing circuit for sensing temperature variations and providing a first signal representative thereof and a temperature measuring circuit which is responsive to the first signal for producing a second signal representative of the temperature being sensed. A display circuit indicates the measured temperature for a predetermined period. There is a power supply, an actuator and an automatic electronic switch responsive to the actuator to turn on and provide power from the power supply to the circuits during an interval at least as long as the predetermined period and to automatically turn off at the end of that interval and cease providing power to the circuit, thereby ending the display.

In preferred embodiments the system may also include a time measuring circuit whose output will be displayed by the display circuit during another period of time. Typically the time is displayed during a first period and the temperature during the next period.

Reference will now be made to the accompanying drawings, in which:—

Figure 1 is a block diagram of an electronic thermometer system using an automatic on-off electronic switch according to this invention;

Figure 2 is a more detailed block digram illustrating one implementation of the system of Figure 1; and

Figure 3 is a more detailed schematic diagram of the automatic on-off electronic switch shown in Figures 1 and 2.

There is shown in Figure 1 an electronic thermometer system 10 including a temperature sensing circuit 12 which senses variations in temperature and provides a signal representative thereof to a measuring circuit 14 which responds by providing a signal representative of the measured

temperature to a control and display circuit 16. Power is supplied to the circuits 12, 14 and 16 from a power supply 17 under the control of an automatic on-off electronic switch 18.

The measuring circuit 14 may include a voltage-to-rate converter or similar analog-to-digital converter which provides a series of pulses, representing the measured temperature, to the control and display circuit 16. The control and display circuit 16 may include counting circuits for counting pulses from the measuring circuit 14 and a digital display for displaying the measured temperature. The control and display circuit may also include a time measuring circuit and a control circuit which causes the alternate display of time and temperature.

The temperature sensing circuit 12 preferably includes a probe 20, Figure 2, for sensing a temperature to be measured and producing a signal representative thereof which is submitted through an internal reference circuit 22 to a bridge circuit 24. The internal reference circuit 22 selectively connects a matching circuit to the bridge circuit 24 in place of the input from probe 20 so that the accuracy and operation of the system can be verified. The bridge circuit 24 provides a reference output on a line 26 and, on a line 28, provides a varying output as a function of the bridge's imbalance: this output is an analog signal which is a function of the temperature sensed by the probe 20. In this system which would be used primarily to take the temperatures of humans, the measurement range is from 90°F to 110°F. The reference output of the bridge circuit 24 represents 90°F; when the output on the line 28 of the bridge circuit 23 is equal to the reference output on the line 26, the probe 20 is measuring a temperature of 90°F. When the output on the line 28 has a predetermined (maximum) deviation from the reference output, the probe 20 is measuring 110°F. The out-of-balance output is fed to an anticipation circuit 30 which senses the rate-of-change of the temperature being sensed by the probe 20 and augments the signal on the line 28 from the bridge circuit 24, thereby providing a signal, at the summing point 32 in the voltage to rate converter 14, representative of the final value of the temperature being sensed in advance of the actual sensing of that final value.

In the measuring circuit 14 the signal at the summing point 32 is directed to the negative input of an integrator circuit 34 whose positive input receives the reference output from the bridge circuit 24. A difference between the signal at the summing point 32 and the reference output at the input to the integrator 34 causes it to provide a positive-going ramp at its output to a pulse generator 36, which provides a (negative-going) output pulse of fixed width when the ramp reaches a predetermined voltage level. The fixed width pulse is delivered along a feedback line 38 to a switch 40 which delivers a positive going pulse having a fixed width and a fixed amplitude to the summing point 32. The presence of this pulse temporarily restores the summing point 32 to the reference level of the output line 26, and thereby causes the integrator circuit's output to fall. Thereby a sawtooth output signal is produced.

The pulse generator 36 then produces no further pulse to the switch 40. Therefore no pulse is delivered to the summing point 32 and the signal level at summing point 32 once again departs from that on the reference output line 26. This departure causes the integrator circuit 34 to provide another positive ramp and the described cycle of operation to recommence. Because the pulses fed back to summing point 32 have a fixed width and a fixed amplitude, then the greater the potential difference between the summing point and the output line 26, the higher must be the repetition rate of the pulses provided at the output of the pulse generator 36; this repetition rate is proportional to the temperature which is sensed by probe 20. The illustrated circuit 14 is but one example of a voltage-to-rate converter which may be used. Instead a voltage-controlled oscillator or other means for producing an output whose frequency varies in proportion to an analog input signal could be used.

The control and display circuit 16 includes a digital counting and decoding circuit 42 which counts the pulses provided at the output of the pulse generator 36 and decodes that count to display the measured temperature on a digital display 44.

A precision voltage regulator 50 provides regulated voltage, PVR, to the bridge circuit 24, the reference current switch 40, the integrator circuit 34, the constant width pulse generator 36 and a sensing circuit 52 which senses when the battery's voltage is too low. The other input to the low sensing circuit 52 is an unregulated current supplied at the output of automatic on-off electronic switch 18. When the unregulated power supply voltage decreases to a predetermined level relative to the regulated voltage output provided by the voltage regulator 50, the sensing circuit 52 provides a signal to the digital counting and decoding circuit 42, causing it to extinguish the least significant digit of the temperature appearing in the digital display 44.

The specific embodiment of the electronic thermometer system 10 illustrated in Figure 2 operates in two modes: a time display mode and a temperature display

mode. Digital control logic 54 supervises the system's performance in each of these modes and controls the transition between them. In the time display mode, the digital control logic 54 passes pulses from a clock 56 to the digital counting and decoding circuit 42 whereas, in the temperature display mode the digital control logic 54 directs pulses from the pulse generator 36 to the digital counting and decoding circuit 42.

The system is operated by the actuation of a start switch 58. When it is actuated, the automatic electronic switch 18 is turned on to supply power from the power supply 17 to the rest of the system; the digital control logic 54 and the digital counting and decoding circuit 42 are reset. The probe 20, which is in contact with the patient whose temperature is to be measured, begins to sense the temperature. As the probe's temperature T increases, the voltage E at the output 28 of the bridge circuit 24 decreases, increasing the negative current I at summing point 32. The potential difference between the output line 26 and the summing point 32 causes pulses to be generated at the output of the pulse generator 36 at a repetition rate required to restore the summing point 32 to its original potential. The repetition rate of the pulses at the output of the pulse generator 36 stabilizes in a short period of time to represent the final value of the temperature being sensed. This time may be reduced still further by the use of anticipation circuit 30 as explained previously.

Simultaneously with this action, upon the actuation of the start switch 58, the switch 18 latches itself to stay on for a predetermined period after the start switch 58 has been operated. In this particular embodiment, in which there is both a time and a temperature measurement and display the period embraces both the duration of the time display mode and the duration of the temperature display mode, e.g. 20 seconds and 10 seconds respectively. A signal to the switch 18 on a line 60 signifies the end of the time display mode and the start of the temperature display mode.

Simultaneously with the actuation of the start switch 58 the digital control logic 54 passes clock pulses from the clock 56 to the digital counting and decoding circuit 42. These clock pulses may have a duration of 100 milliseconds so that a count of ten such clock pulses by the digital counting and decoding circuit 42 indicates the passage of one second. At the end of each second so indicated the digital display 44 is enabled to display the number of seconds which have elapsed since the commencement of counting. At the end of the twentieth second the digital control logic 54 transfers the system into the temperature display mode by permitting the passage, for the duration of one clock pulse, of the pulses at the output of the pulse generator 36 to the digital counting and decoding circuit 42 which accumulates and decodes the count and causes the temperature to be displayed.

The switch 18 preferably includes a switching circuit 70 (Figure 3) including a transistor 72 having its emitter 72 connected to the positive terminal 76 of the power supply and its collector 78 connected to a positive power line 80. The transistor 72 is held normally in a non-conducting state by means of a resistor 82, which is connected between the base 84 and the emitter 74 of the transistor 72 and which keeps the base 84 within six-tenths of a volt from emitter 74. In the switching circuit 70 a resistor 86 holds the base 88 of a transistor 90 within six tenths (0.6) of a volt from ground potential so that the transistor 90 is also normally in a non-conducting state. The emitter 92 of the transistor 90 is connected to ground and the collector 94 is connected through a resistor 96 to the base 84 of the transistor 72. When the start switch 58 is closed the potential at the base 88 of the transistor 90 moves towards that of the terminal 76 and the transistor 90 is rendered conductive. Current is drawn through the resistor 96 to drive the base 84 of the transistor 72 towards ground. The transistor 72 thereupon conducts and supplies power to the rest of the circuit *via* the line 80.

The pressing and releasing of start switch 58 provides a positive pulse on a line 98 to a timing circuit 100 which includes a bistable multivibrator 102. The signal on the line 98 is delivered to the set input of the bistable multivibrator 102 causing its Q output 104 to go "high". The diode 106 is thereby forward biased and a signal is provided on line 108 to charge a capacitor 110 in a timing circuit 111. The signal is fed back through an amplifier 112 and a resistor 114 in a latch circuit 116 to the base 88 of the transistor 90, thereby maintaining the conductive state thereof. The transistor 72 continues to conduct and the switch 18 is securely latched. A resistor 118 connects one pole of the start switch 58 to ground and a resistor 120 connects the reset input R of the bistable multivibrator to ground. After a predetermined time, in the specific system shown in Figure 2, a signal on the line 122 signifies the end of the time display mode and resets the bistable multivibrator 102. The diode 106 is now back biased by the lower signal on the Q output 104 and so the capacitor 110 discharges through the resistor 124 for a predetermined period of time (e.g. ten seconds) while the temperature is being displayed in the temperature mode. When the potential on the line 108 falls, the signal fed back through the

latch circuit 116 to base 88 of transistor 90 diminishes. The transistors 90 and 72 revert to a non-conductive state and the flow of power to the rest of the system is automatically blocked. The interval during which automatic on-off electronic switch 18 remains energized need not necessarily include two periods; it may include only one period or more than two periods. If the temperature display period is the only one utilized,the temperature display period may be delayed for a short time after the interval begins in order to permit the temperature measuring circuit of the system to stabilize at a final temperature value.

WHAT WE CLAIM IS:—

1. An electronic thermometer system comprising a temperature sensing circuit for sensing temperature variations and providing a first signal representative thereof; a temperature measuring circuit responsive to said first signal for producing a second signal representative of the temperature being sensed; a display circuit for indicating the measured temperature for a predetermined period; a power supply; an actuator; and an automatic electronic switch responsive to said actuator to turn on and provide power from said power supply to said circuits during an interval at least as long as said predetermined period and automatically turn off at the end of said interval, cease providing power to said circuit and end the display.

2. The system of claim 1 in which said automatic electronic switch includes a first semiconductor device for controlling power flow from said power supply and a second semiconductor device responsive to said actuator device for operating said first semiconductor device.

3. The system of claim 1 in which said automatic electronic switch includes a latching circuit for holding said automatic electronic switch in the on condition during said interval independent of the subsequent condition of said actuator device.

4. The system of claim 3 in which said automatic electronic switch includes a timing circuit for defining the length of said interval.

5. The system of claim 4 in which said interval includes a plurality of periods and said timing circuit includes a timing network for setting each period.

6. The system of claim 1 in which said system further includes a time measuring circuit and said interval includes said predetermined period during which temperature is displayed and another period during which the time is displayed.

7. The system of claim 6 in which said period in which the time is displayed occurs first in said interval.

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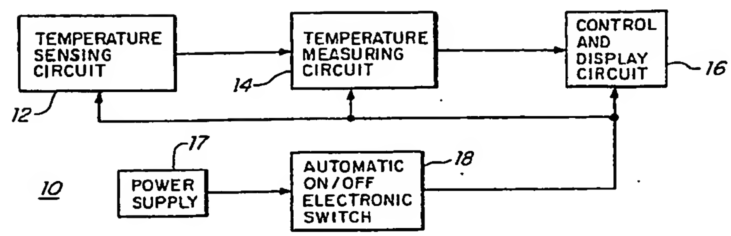
TEMPERATURE SENSING CIRCUIT
TEMPERATURE MEASURING CIRCUIT
CONTROL AND DISPLAY CIRCUIT
POWER SUPPLY
AUTOMATIC ON/OFF ELECTRONIC SWITCH
12
14
16
17
18
10

FIG. 1

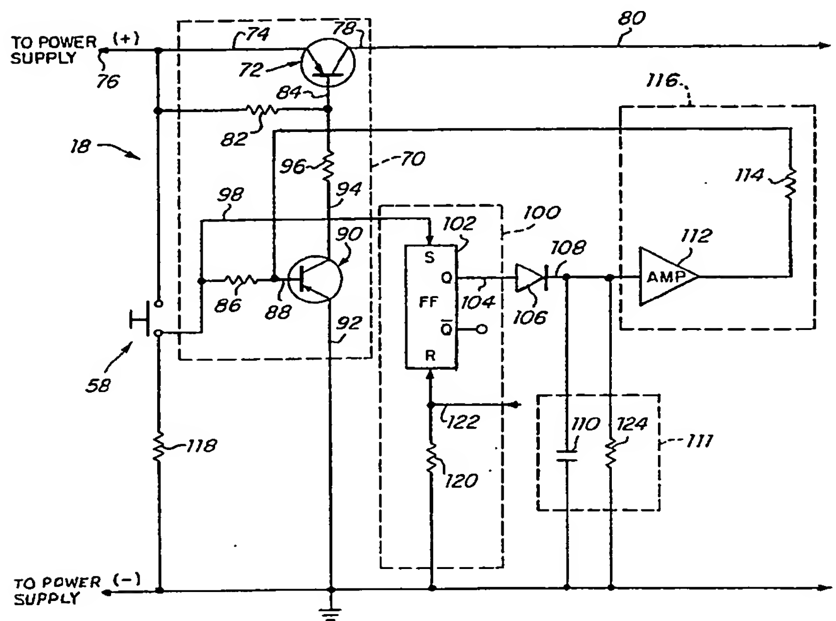
TO POWER SUPPLY (+)
TO POWER SUPPLY (-)
AMP
FF
S
Q
R
18
58
70
74
76
78
80
100
111
116

FIG. 3

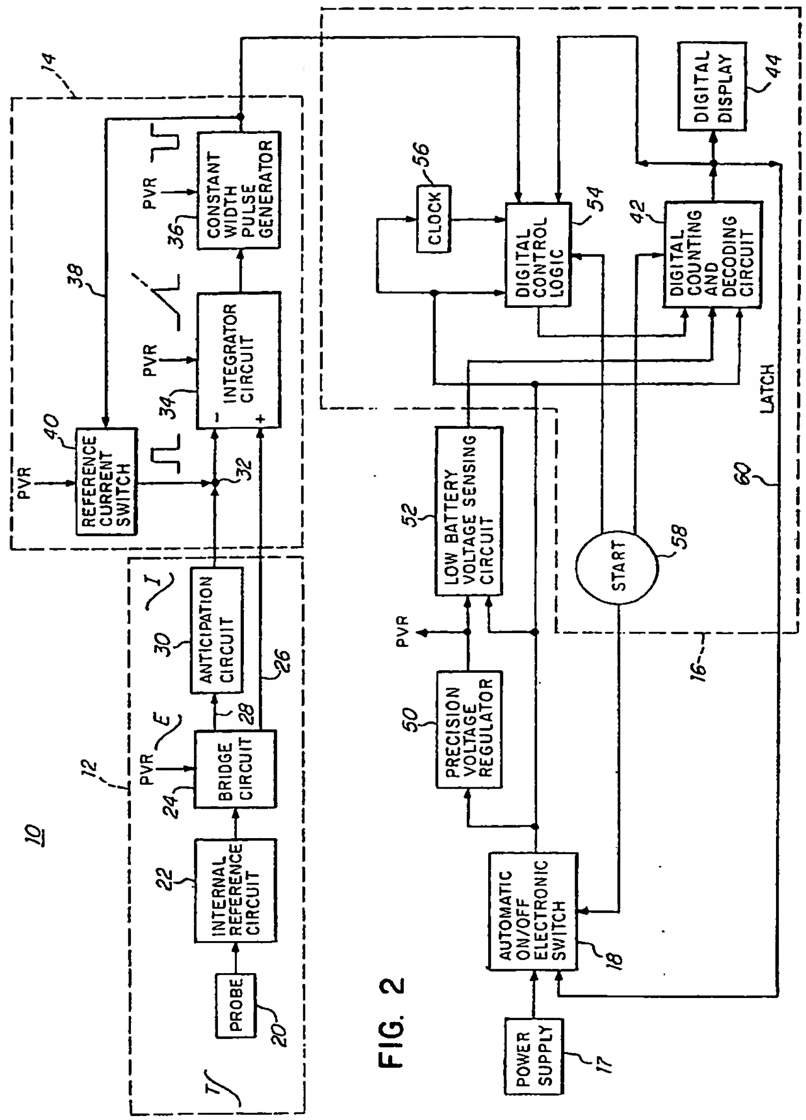
10
14
12
16
PROBE
20
INTERNAL REFERENCE CIRCUIT
22
BRIDGE CIRCUIT
24
PVR
E
28
26
ANTICIPATION CIRCUIT
30
I
T
REFERENCE CURRENT SWITCH
40
PVR
32
INTEGRATOR CIRCUIT
34
PVR
38
CONSTANT WIDTH PULSE GENERATOR
36
PVR
POWER SUPPLY
17
AUTOMATIC ON/OFF ELECTRONIC SWITCH
18
PRECISION VOLTAGE REGULATOR
50
PVR
LOW BATTERY VOLTAGE SENSING CIRCUIT
52
START
58
CLOCK
56
DIGITAL CONTROL LOGIC
54
DIGITAL COUNTING AND DECODING CIRCUIT
42
DIGITAL DISPLAY
44
LATCH
60

FIG. 2